TITLE OF INVENTION

Netw rk H aling Smart Fiber Optic Switch

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a Continuation-In-Part of Serial Number 09/649,455, filed on August 25, 2000.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

BACKGROUND OF THE INVENTION

1. Field of Invention

[0003] This invention pertains to optical fiber switches for switching optical transmission paths. More particularly, this invention pertains to a fiber optic switch which can switch between incoming optical transmission paths based upon the quality or condition of the signal being transmitted.

2. Description of the Related Art

[0004] Optical fibers are commonly used for the transmission of all types of data, including telecommunications, video, and computer data. Fiber optic cables have become an alternative to conventional wire transmission. The advantages of fiber optic cables over wire include greater bandwidth over greater distances with less loss and less cost. Fiber optic cables are considerably less susceptible than metal conductors to unauthorized "taps" and eliminate RF problems and the need for electrical isolation interfaces such as isolators. Because of these advantages, fiber optic cables often are used as an alternative to wire in networks.

[0005] Typically, fiber optic cables are used to form a transmission line from an origination point to a destination point. Because of the great bandwidth of optical fiber, many times the fiber optic cable transmits in both directions, so that

the origination point for one direction is also the destination point. Depending upon the length of the transmission line, lengths of fiber optic cable may have to be spliced, and the optical signal may have to be amplified in order to maintain the signal strength at the destination point. Along the transmission line, taps and routers may be used so that either portions of or all of the optical signal can be delivered to multiple destinations. Because of their widespread use, fiber optic networks oftentimes have complex topologies and numerous components, and accordingly, are subject to various faults. These faults may develop over a period of time and be evidenced by a slow degradation of signal quality and strength, as in dirt and grime accumulating at connection points and obstructing the cable's optical interface. Other faults may be catastrophic and occur suddenly, as in a cable being cut by an outside force or by failure of an upstream device.

[0006] United States Patent Number 5,710,846, titled "Self-calibrating optical fiber switch," issued to Wayman, et al., on January 20, 1998, discloses a microprocessor controlled optical routing switch that samples the input signals and compares them to a reference calibration value. The switch disclosed in Wayman, et al., switches out an input when the sampled signal quality for that input degrades by an amount greater than a preset threshold value.

[0007] United States Patent Number 5,726,788, titled "Dynamically Reconfigurable Optical Interface Device Using an Optically Switched Backplane," issued to Fee, et al., on March 10, 1998, discloses optical switches used in a dynamically reconfigurable optical telecommunications network. The switches disclosed in Fee, et al., are used for routing optical signals and are controlled by a microprocessor.

[0008] There is a need to provide fast, intelligent fault recovery when a fiber optic cable no longer carries a signal. Fault recovery needs to occur with little delay because with a great bandwidth, long out-of-service times result in the loss of a great amount of data and information.

BRIEF SUMMARY OF THE INVENTION

[0009] According to an embodiment of the present invention, a network healing smart fiber optic switch assembly is disclosed comprising an optical switch responding to a controller which monitors multiple paths of an optical transmission line. Each fiber optic input is split into two signal paths, one containing a majority of the signal strength feeding the optical switch and the other feeding the controller, which, using an analog circuit, senses the quality or condition of each fiber optic input. A fault on the primary fiber optic cable causes the network healing smart fiber optic switch to switch to a secondary fiber optic cable within a selected amount of time and preferably within 10 milliseconds. After the fault is corrected and the signal on the primary fiber optic cable is stable for a period, the switch restores the primary fiber optic cable path. Faults on a fiber optic cable are defined as a degradation of signal strength below a threshold, or setpoint, level or the complete loss of the optical signal. Other embodiments define faults as a change in color or frequency of the optical signal. The network healing smart fiber optic switch is also controlled locally and remotely via a buss connection with another computer or controller.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0010] The above-mentioned features of the invention will become more clearly understood from the following detailed description of the invention read together with the drawings in which:

Figure 1 illustrates a flow diagram of the network healing smart fiber optic switch;

Figure 2 illustrates a block diagram of the preferred embodiment of the network healing smart fiber optic switch;

Figure 3 illustrates a block diagram of the network healing smart fiber optic switch with multiple inputs and multiple outputs;

Figure 4 illustrates a block diagram of the circuit elements of the network healing smart fiber optic switch;

Figure 5 illustrates a simplified schematic diagram of a portion of the network healing smart fiber switch; and

Figure 6 illustrates a block diagram of a portion of the analog selection circuit.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Referring to Figure 1, a flow diagram of the network healing smart fiber optic switch **10** has a plurality of inputs feeding a splitter **102**. Each input is split into two signals, one going to the optical switch **106** and the other going to the controller **108**. The controller **108** senses the condition of the signals from the splitter, and based on the sensed condition, which can be optionally overridden by either local or remote control, the controller **108** sends a control signal to the optical switch **106**. The optical switch **106** switches, or routes, the signals from the splitter to the output, based on the control signal from the controller **108**.

[0012] In Figure 2, the network healing smart fiber optic switch **10** has two fiber optic inputs representing two paths of an optical transmission line, one of which is passed through to the output. A fiber optic cable is connected to input A **214a**. The optical signal from input A **214a** is divided into two paths by splitter A **212a**. The primary path, which consists of approximately 95% of the optical signal strength, goes to the optical switch **216**. The secondary path, corresponding to approximately 5% of the optical signal strength, goes to the controller **218**. Those skilled in the art will recognize that the division of the signal between the primary and secondary paths is not critical, and that if less than 95% signal strength is used for the primary path because the controller **218** sensing means requires more than 5% of the signal strength, the primary path signal strength can be increased by amplification at any point in its path. A second fiber optic cable is connected to input B **214b** and is processed in a manner similar to the first fiber optic cable.

[0013] The optical switch **216** accepts inputs from splitter A **212a** and splitter B **212b**. The optical switch **216** is responsive to a control signal from the controller **218**. The control signal causes the optical switch **216** to select and pass through to the output **220** one of the two inputs from splitter A **212a** or splitter B

212b. The optical switch **216** is capable of switching between inputs within a short period.

[0014] The controller **218** is an analog selection circuit that senses the optical signals from splitter A **212a** and splitter B **212b** and has logic which determines which optical signal has the greatest optical signal strength. The controller **218** is responsive to local control which serves to override the controller **218** output. Also, the controller **218** is responsive to a buss connection **219**, which puts the controller **218** into communication with a remote computer or other device and serves to provide control instructions to the controller **218**. The controller **218** outputs a control signal to the optical switch **216** which causes the optical switch **216** to select and pass through to the output **220** one of the two inputs from splitter A **212a** or splitter B **212b**.

[0015] In the illustrated embodiment, the controller **218** includes a photodiode, which senses the signal level from each fiber optic cable input. The controller **218** also includes logic which determines if the fiber optic signal passing through to the output has an optical signal strength, as sensed by the photodiode, which has fallen below a specified threshold value. If it has, the controller **218** causes the optical switch **216** to switch to the signal from another fiber optic cable. The optical switch **216** completes the switchover within a specified period, preferably within 10 milliseconds or less, effectively bypassing the fault, whether caused by a gradual signal degradation or equipment failure, with minimal disruption to the transmitted signal. After causing the optical switch **216** to operate, the controller **218** will inhibit further switching action for a specified period, effectively preventing rapid oscillation between the input signals. Those skilled in the art will recognize that means for sensing the optical inputs and parameters other than signal strength may be used without departing from the spirit or scope of the present invention. An alternative embodiment of the controller **218** includes logic which compares the primary fiber optic cable's optical signal strength to that of the other fiber optic cable's optical signal strength, and causes the optical switch **216** to switch to the fiber optic cable which has the greater signal strength.

[0016] Referring to Figure 3, another embodiment of the network healing smart fiber optic switch **10** is shown as having multiple inputs (**214a** through **214y**) and multiple outputs (**220a** through **220x**). The controller **218** causes the optical switch **216** to switch any input to any output, based on the logic of the controller **218**, the sensed condition of the inputs, and any overriding signal from a local controller or remote source communicating through the buss connection **219**. As in the preferred embodiment described above, the condition sensed is a fault condition as determined by the signal strength of an input degrading below a threshold value. An alternative embodiment of the controller **218** permits communication with other network healing smart fiber optic switches **10** or computer systems such that, working in conjunction with other network healing smart fiber optic switches **10** or other devices, network paths may be rerouted to bypass fault conditions and accommodate network loading.

[0017] Those skilled in the art will recognize that there are additional alternative embodiments for the network healing smart fiber optic switch **10**. For example, in one embodiment, the controller **218** causes the optical switch **216** to switch based on the presence or absence of a particular color or wavelength in the optical signal. In another embodiment, the optical switch **216**, in conjunction with other optical switches, is capable of combining the optical signals from two or more input signals to produce a single, composite output signal with the combination occurring based on the condition of the optical signals.

[0018] Figure 4 illustrates a block diagram of one embodiment of the circuit elements of the network healing smart fiber optic switch **10**. The two splitters **402A** and **402B** each receive an external optical signal. Each splitter **402A** and **402B** outputs an optical signal **404A** and **404B**, which is routed directly to the optical switch **406**. Each splitter **402A** and **402B** also outputs a portion of the input as an electrical signal **408A** and **408B**, which is routed to the analog selection circuit, or controller, **218**.

[0019] One optical signal **404A** is considered the primary optical signal and the other optical signal **404B** is considered the secondary optical signal. The conversion of the split optical signal to an electrical signal **408A** and **408B**, which

is typically done with an photodiode, is included in the function of either the splitter **402** or the amplifier **412**. The amplifiers **412A** and **412B** receive signals **408A** and **408B** from the splitters **402A** and **402B** and output signals to input signal comparators **414A** and **414B**, which compare the amplifier **412A** and **412B** output signals to a setpoint value **416**. The two comparators **414A** and **414B** output to a holding circuit **422** which outputs signals to an output comparator **424**, which outputs to a switch **426** that controls an indicator **428** and the optical switch **406**. The output of the A comparator **414A** indicates that the primary optical signal **404A** is valid, or a good signal, when the signal **408A** exceeds the setpoint **416**, and indicates that the primary optical signal **404A** is invalid, or not a good signal, when the signal **408A** does not exceed the setpoint **416**. The output of the B comparator **414B** indicates that the secondary optical signal **404B** is valid, or a good signal, when the signal **408B** exceeds the setpoint **416**.

[0020] Figure 5 illustrates a simplified schematic diagram of one embodiment of the holding circuit **422**. The function of the holding circuit **422** is determined by the position of a manual mode switch **SW1**. With the switch **SW1** open, the holding circuit **422** causes the optical switch **406** to switch to the B input **408B** upon failure of the A input **408A** and to maintain that path until failure of the B input **408B**, at which time the holding circuit **422** resets to the default of passing the A input **408A**. The positive feedback/pull-up resistor **R5** maintains the B input **408B** high after the B input **408B** is selected.

[0021] With the switch **SW1** closed, the holding circuit **422** causes the optical switch **406** to switch to the B input **408B** upon failure of the A input **408A** and to maintain that path until the A input **408A** has been restored and been stable for a time determined by the RC network **C1** and **R4**. After the A input **408A** has remained stable and charged the capacitor **C1**, the input of the Schmitt trigger **507** increases to its threshold value and the output of the trigger **507** goes low, causing a current flow through the switch **SW1** and the diode **D3** and forcing the B input **524B** to a voltage less than the voltage of the A input **524A** to the output comparator **424**, which is equal to the output voltage of the A comparator **414A**.

[0022] An analog selection circuit **218**, such as that shown in Figure 4, has the speed to quickly switch out a failing optical signal, that is, an optical signal that has a level that falls below the setpoint **416**. In one embodiment, illustrated in Figure 5, Maxim MAX908 comparators, Maxim MAX494 op-amps, and Fairchild MM74HC14 Schmitt triggers are used, and the circuit has a switching time of less than 10 milliseconds. In another embodiment, the signal to the indicating lamp **428** is also output to a computer system or other controller for status monitoring by the remote system.

[0023] Figure 6 illustrates a block diagram of a portion of the analog selection circuit **218**, including the holding circuit **422**. The setpoint comparators **414A** and **414B** output to a comparator **424**, which routes the secondary optical signal **404B** upon the primary optical signal **404A** becoming invalid. This arrangement ensures that the primary optical signal **404A** is routed under normal conditions. The A setpoint comparator **414A** outputs to a timing circuit **602**, which starts a timing cycle when a failed or faulted primary signal **408A** is restored or again becomes valid. The timing circuit **602** resets when the A comparator **414A** senses that the signal **408A** is below the setpoint and invalid, i.e. failed or faulted. The timing circuit **602** outputs a signal to the deselect circuit **604** after a selected time passes in which the restored primary signal **408A** has been valid and stable. The deselect circuit **604** has an input from the B setpoint comparator **414B** and outputs to the output comparator **424**. In the embodiments illustrated in Figures 5 and 6, the B input to the output comparator **424** is held high after the secondary optical signal **404B** is selected, and the deselect circuit **604** pulls that input down to select the primary optical signal **404A** after the primary optical signal **404A** has been valid for a selected period.

[0024] From the forgoing description, it will be recognized by those skilled in the art that a network healing smart fiber optic switch **10** offering advantages over the prior art which has been provided. Specifically, the network healing smart fiber optic switch **10** is a fast, automatic switch that permits switching between multiple paths of an optical transmission line with minimal disruption. Also, the network healing smart fiber optic switch **10** is capable of communicating with

other computers and controllers, permitting the network healing smart fiber optic switch **10** to be remotely controlled.

[0025] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. The invention in its broader aspects is therefore not limited to the specific details, representative apparatus and methods, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.